Let's Talk Context!

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Abstract: *In this article, the author challenges popular lore that students hate "story problems," offering ideas for how to select and teach with contextual modeling tasks to make the most of their potential to engage students. Tips are based on observations, interviews, and surveys with students in two 7th-grade classrooms.*

Keywords: *mathematical modeling, student engagement, contextual tasks*

1 Introduction

For most of us, the phrase "story problem" probably doesn't invoke thoughts of engagement and motivation. In fact, I remember a time when assigning them elicited groans and near-panic in some students. But I have also seen that when teachers make the most of the engagement potential of story problems, they can become a class favorite!

However, I don't focus on story problems (or word problems) in the traditional sense only. Traditional story problems tend to be exercises involving a routine application of a familiar procedure. In contrast, the current trend in mathematics education is to use more open-ended modeling tasks (NGA Center & CCSSO, 2010). See Table 1 for examples of each.

Table 1: Traditional story problem and modeling task samples (adapted from Larson, Boswell, Kanold, & Stiff (2001))

Sample Story Problem	**Sample Modeling Task**
Your starting salary as a veterinary technician is $18,000 per year. You will receive a $750 raise each year. Write an equation in slope-intercept form for your salary s in terms of the number of years n since you started as a technician. Use your equation to calculate your salary after 6 years.	You are comparing costs of renting a bus for one day for a school field trip. Cheap Rentals charges $120 per day plus $2 per mile. Easy-Rent Agency charges a flat fee of $300 for the day. Which company offers the better deal? Write a sample note to your principal to explain which company she should choose, and why. Use at least two representations to justify your answer.

Modeling involves taking a real-world situation (context) and translating it into the mathematical world by finding a representation for the situation (Niss, Blum, & Galbraith, 2007; Usiskin, 2015). These tasks have greater complexity in their storylines, better reflect students' experiences, and

serve as an arena in which to develop new mathematical understanding. I am interested in the impact of a range of problems—from traditional story problems to modeling tasks drawn from realistic or imaginative scenarios—so I use the term contextual task for any problem that involves a non-mathematical storyline.

As math teachers, one of our toughest but most important jobs is to engage and motivate our students. Students' attention is pulled in many directions, but their engagement is vital for problem solving and participating in meaningful class discussions. We know that our teaching has the potential to encourage student engagement and motivation through specific activities (Middleton & Jansen, 2011, Turner & Meyer, 2009). Contextual tasks are a long-standing and important part of school mathematics (NCTM, 2000, 2014; NGA Center & CCSSO, 2010), and under certain circumstances may be a convenient resource to boost student engagement (Hernández, Levy, Felton-Koestler, & Zbiek, 2016). In this article I explore a number of lessons and activities designed to promote student engagement, examine the impact that contextual tasks played in their implementation, and share tips on selecting and facilitating discussions around contextual tasks to promote student engagement.

2 The Study

The ideas that I present are based on my observations and conversations with students in two 7th-grade classrooms. My research explores possible reasons for differing engagement levels across several lessons—including some that included contextual tasks and others that did not. I considered both *emotional engagement* (student affect such as happiness, excitement, or boredom) and *cognitive engagement* (investment in learning content, including challenge seeking, hard work, and self-regulation) (Fredericks, Blumenfeld, & Paris 2004; Helme & Clarke, 2001). To study the relationship between the nature of tasks and student engagement, I conducted 28 weekly observations (23 of which focused on contextual tasks), focus group interviews with students, and teacher and student surveys.

Both participating teachers, Mrs. Meyer and Mrs. Pearson, used the problem-based curriculum *Connected Mathematics Project* (CMP) (Lappan et al., 2006) in their classrooms. A typical lesson followed a three-phase "launch, explore, summary" structure. In the launch phase, the teacher introduced the main problem for the day and focused students' attention on key concepts. Students worked on one core problem in pairs or small groups during the explore phase, while the teacher listened to their discussion, posed questions, and provided scaffolding with the groups as needed. The explore phase took a majority of the class time. Finally, the teacher facilitated whole-class discussions summarizing students' strategies, solutions, and reasoning. Daily problems were organized into thematic units, each of which lasted about five weeks.

After collecting data for the 28 lessons, I identified the most and least engaging lessons by considering evidence of student engagement in class (e.g., asking a relevant question or sharing a mathematical idea in a discussion) along with teachers' ratings and student self-reports. Then, I characterized the tasks in those lessons as written and enacted. Below, I share findings that stood out as particularly important to teaching.

3 Lessons with Low and High Engagement

All six of the most engaging lessons (three from each 7th-grade classroom) were designed around contextual tasks, whereas only three of the six least engaging lessons included contextual tasks. This

counters the popular lore that "story problems" are the worst part of school mathematics. Tasks from the most and least engaging lessons are described in more detail in Tables 2 and 3, respectively.

Table 2: Contextual tasks in high-engagement lessons

Task	Description	Learning Goal(s)
Cola Survey	A soda company conducts a taste test. The results are given as four possible statements to be used in an ad, including, "people who preferred Bolda Cola outnumbered those who preferred Cola Nola by a ratio of 17,139 to 11,426" or "5713 more people preferred Bolda Cola."	Explore how different types of comparisons of quantities (ratios, percentages, differences) communicate different information about the relationship between the quantities.
Wumps and Imposters	Fictional students Zach and Marta are designing and programming a computer game involving characters called *Wumps* (who are similar figures). Students determined which characters are Wumps and which are *imposters*. In later lessons, they explored specific features of the characters.	Make conjectures about what coordinate rules (e.g., $(x, 3y)$ or $(2x, 2y)$ generate similar figures.
Bike Trip	A man named Sascha is going on a bike trip comprising three legs. Students are given the length of each leg and how many minutes it took to finish. Then, they found and compared unit rates and considered how fast they would need to ride to race Sascha.	Calculate and interpret rates and the relationship between distance, rate, and time.
Mystery Teacher	The Mystery Club at a middle school is determining the height of a "mystery teacher" from a photograph so they can figure out the teacher's identity. The image is a drawing of a teacher in disguise standing next to a rack of magazines.	Explore what it means for two figures to be mathematically similar; develop strategies to indirectly find lengths using a photograph.

Note that *The Wumps and Imposters* context appeared in three highly engaging lessons between the two classrooms.

Table 3: Contextual tasks in low-engagement lessons

Task	Description	Learning Goal(s)
Apples and Oranges	Students interpreted equations and expressions involving the number and price of eggs, apples, and bananas. The task did not have a storyline, other than the single statement, "suppose you are buying apples and bananas in a shop," which was in the suggested script for teachers and not the students' version.	Connect algebraic expressions and equations to real-life situations, addressing misconceptions related to the meaning of variables in expressions and equations.
Multiple applications	The lesson's main task included four different contexts: estimating puffin populations, determining how many miles a jet would take to descend 5280 feet, estimating the number of calories Jack consumed when he ate enchiladas over the course of a year, and comparing a middle school population with the numbers of students on student council by grade.	Develop general strategies for solving problems involving proportions.
Money Models	The class reviewed an assignment on integer operations, including multiple problems in which the actors mow lawns, walk dogs, and borrow money from their siblings; or more generally, spend, earn, and owe money.	Use the chip model to represent number sentences with addition and subtraction of integers.

4 What are the characteristics of an engaging context?

Surprisingly, some characteristics of the contexts as written that are hypothesized to be important, such as age-appropriateness and personalization, did not seem to significantly affect student engagement. The sets of most and least engaging tasks both included a mix of student-oriented contexts (*Wumps, Mystery Teacher*) and age-neutral contexts, appropriate for teens or adults (*Cola Survey, Bike Trip*). Research shows that personalizing a context can increase student engagement (Cordova & Lepper, 1996; Walkington, Sherman, & Petrosino, 2013), so it was perhaps most remarkable that none of the problems drew on personalized or community-based contexts. It's worth noting, however, that it was apparent in student classwork and follow-up surveys and interviews that they at least found each of the contexts relatable. So although the stories may not have been personally relevant, they offered something for students to visualize and discuss. Next, I

discuss what did seem to distinguish highly engaging tasks from the least engaging tasks in terms of task characteristics and their implementation.

4.1 Role of Context and Purpose of Task

The clearest distinction between contextual tasks in the most and least engaging lessons was the *role of the context* and the *purpose of the task*. All of the highly engaging tasks had features of modeling tasks with a single, strong storyline—*The Bike Trip*, *The Mystery Teacher*, and so on. Most of these task prompts were open-ended and phrased in terms of the story. That is, the core question students explored was contextual. Questions posed by the teachers included:

- Who is a Wump, and who is an imposter?
- How tall is the teacher, and how can we use the picture to figure it out?
- Which statement would you use in the cola ad?

When teachers launched tasks in this way, it gave the contexts a central role in students' problem solving—students could not answer the questions asked unless they paid attention to the context. Also, the open-endedness of the modeling tasks gave students opportunities to use multiple, varied strategies. In contrast, the tasks in the lessons with low engagement were written more like traditional story problems, items that students can solve without paying attention to complexities of the real-life scenario.

In the highly engaging lessons, the purpose of the contextual tasks was usually to introduce new ideas or to give students opportunities to explore and get strategies out on the table. In contrast, the tasks that had low engagement came later in a unit, when students could apply established strategies to the context. These tasks reflected more traditional story problems. For example, the *Multiple Contexts* task was the last task in the unit where the purpose was to synthesize and review students' knowledge about proportions.

4.2 How We Use Contexts Matters

Teachers and students discussed contexts in unique ways in the most engaging lessons. Across these lessons, three qualities stood out with respect to the enactment of core tasks. I illustrate each of the three features through students' work on the *Wumps and Imposters* task. In this lesson, students were given a table of coordinate points to graph and connect to create the figure "Mug Wump." Then, they were given coordinate rules (e.g., Zug's rule is $(2x, 2y)$). Students constructed graphs to determine if the new figure is mathematically similar and thus in the Wump family or is a nonsimilar "imposter." The learning goal is for students to develop understanding of similarity by making and testing conjectures about what rules generate similar figures (Lappan et al., 2006).

4.2.1 Teachers talked about the contexts more, and in more diverse ways

This was especially true in the launch phase of the lesson when teachers were setting up the task. Some ways they talked about context that supported engagement included the following:

- Clarifying aspects that are potentially confusing,
- Inviting students' personal stories related to the context and sharing their own,
- Relating the context to student experiences, and
- Expressing positive feelings toward the problems.

For example, when Mrs. Meyer launched the *Wumps* task, she started by inviting students to identify their favorite games. She asked, "Once you have the focus question on your paper, I want you to think about what your favorite game is on your computer, your tablet, app on your phone or your parent's phone; or a video game." She asked several students to share favorites, then presented a short video on computer animation, which helped clarify that part of the context. The following passages from class discussion illustrate how the teachers talked about the context to support engagement.

> Have you ever thought about that while you're playing those games? Like thought about who was the programmer behind the scenes who put it all together? Can you imagine all the things they have to enter into the computer to get those graphics to move the way you want them to move?
>
> I have to tell you guys that this is one of my favorite problems$\cdots$[it's] just so much fun! What you will notice is that Zach and Marta's computer program involves a family called the Wumps $\cdots$ and let me tell you, you will not forget the Wumps.
>
> [Slyly] We have some imposters here, too. We have some people who want to be in the Wump family, but they aren't similar. They are the imposters. So what you're going to be doing today is working with several rules that Marta has put together for Zach and playing with all these rules and coordinate points. And you are going to be finding out who is actually in the Wump family, or who is similar, and who are the imposters, who are not similar.

In this launch, Mrs. Meyer spent significant time talking with students about the computer programming and the Wumps contexts. She related students' experiences to the context by encouraging discussion of favorite games while making connections to mathematical concepts by asking students to reflect on what might be involved in computer animations. Throughout the launch, Mrs. Meyer spoke positively about the context, describing it as fun, unforgettable, and her favorite—in short, worth engaging. From that point, the Wumps context was central in solving the task. Mrs. Meyer referenced it throughout the lesson. Rather than stripping away the storyline, Mrs. Meyer continued to use the language of characters, Wumps, and imposters when discussing the rules and shapes. For example, during the explore phase, she encouraged a student to connect the context and coordinate rules, asking, "Why is Glug so skinny?" The other highly engaging lessons showed similar patterns of presentation and discussion.

4.2.2 More of students' engagement focused on contexts in the high-engagement lessons

This may have been because of the nature of those tasks, or because the students followed their teacher's lead when it came to how they discussed and worked with the contexts. Students focused on contexts in three main ways: a) they commented on the context separate from the mathematics, b) they used contexts to make sense of and solve problems, and c) they connected contexts with core mathematical concepts. Students were more likely to connect the context with the mathematics in the most engaging lessons. That is, students didn't just like the contexts—the contexts served to bring students deeper into the mathematics.

In Mrs. Meyers' class, for example, students made comments about the Wumps separate from the mathematics, saying things like, "Oh, he looks cool.", "He looks funny!", and "He looks suspicious!" while calculating and plotting coordinates. But in other cases, they used the Wumps to make sense of and solve the task, such as when a student noted, "It [the imposter] has to be Glug or nobody. Everybody else fits in." Another student began to connect the character shapes to the coordinate rules. "The y goes up and down. So for Glug, the y-axis—he's tall, and the y-coordinate is three

times, so he's going to be taller, and Lug, he's going to be wider because it's $3x$." In the summary, a student was excited to discover (or come up with language for) the relationship between Zug and Mug Wump, exclaiming, "Zug looks like, just a, a blown-up Mug. They're similar!" In this last example, we see evidence that the context gave students a foothold to think and talk about mathematical similarity.

4.2.3 Engagement peaked when teachers "opened up" the tasks

In the last section, I noted that teachers abandoned scaffolded written tasks and posed more open-ended contextual questions in the highly engaging lessons. That is, they modified the tasks to better support student mathematical modeling. (Editor's note: See Wernet, Lawrence, & Gilbertson (2015) for specific ways to open up problems in your textbook to give students opportunities to develop their modeling skills.) For instance, Mrs. Meyer opened the *Wumps* task by asking students to differentiate the Wumps and Imposters, allowing them to make conjectures about the coordinate rules. The *Cola Survey* task—in its original format—consisted of several parts that scaffolded student thinking towards ratios and ways to represent them. Mrs. Pearson took the original task and opened it up by eliminating the scaffolding, opting to show the four comparison statements and asking students which they would choose. Students were able to draw on prior mathematical knowledge of fractions, ratios, and percents along with everyday knowledge about taste tests and advertisements to answer the question. Then, students were able to contribute to the core mathematical concepts (making comparisons between numbers) in the summary discussion.

5 Tips and Suggestions for Preparing Lessons with Contextual Tasks

Table 4 offers advice for teachers considering the use of contextual tasks in their classrooms. The table lists characteristics of more and less engaging tasks.

Table 4: Characteristics of the most and least engaging contextual tasks

More engaging tasks ⋯	**Less engaging tasks** ⋯
Could be imaginative/whimsical (Wumps) or realistic (Bike Trip) contexts	Each context was realistic
Contexts were central in problem solving	Contexts were peripheral in problem solving
Purpose was often to introduce new ideas or to give students opportunities to explore and communicate multiple strategies	Purpose was to apply established procedures
Often appeared at or near the beginning of the unit or an Investigation	Appeared later in units
Encouraged open-ended modeling strategies without directing students toward a particular mathematical concept	Encouraged a single solution strategy where students could apply established procedures

With respect to the first two rows of Table 4, one may question whether we want our students to be caught up in the context. I argue *yes*, to the extent that doing so supports student engagement with relevant mathematical ideas. Contextual tasks can indeed engage student—but why? It seems contexts promote engagement in multiple ways: (a) by offering a likable or interesting story, (b) by providing a way for students to access the mathematical ideas, and (c) by anchoring more abstract ideas in a concrete and shared scenario (Berry & Ellis, 2013; Hernández et al., 2016). Teachers strengthened these potential benefits through specific ways they launched and used the contexts.

When we have a task that matches some characteristics in Table 4 and has potential to catch student interest and engage them in thinking hard about a problem, we can plan for it. Table 5 offers some key questions to consider. You may boost the potential of the task to engage students by asking yourself about the nature of the context, how your unique classes will relate to it given their cultural and social experiences (Berry & Ellis, 2013; Felton, 2010), and the openness of the task overall. Then, you can modify a task or thoughtfully orchestrate a discussion that makes the most of what the context offers.

Table 5: Questions to consider when planning a lesson around a contextual task to maximize potential to engage students in the mathematical ideas

While planning	**While enacting**
1) Is the context familiar or relatable for students? *–If not, could I substitute a different, more relevant context?*	Are students using the context appropriately to make sense of the math? *–If not, are they focusing too much on the context (ignoring relevant mathematical resources) or too much on the math (not tapping into prior everyday knowledge)?*
2) Are there multiple, flexible ways for students to use the context in problem solving?	
3) Is the context an application of the content or the foundation of mathematical modeling? *–If it is an application of an established skill or procedure, how can I launch the problem to make the context more central in students' problem solving?*	What could I ask or say to help students meaningfully connect this mathematical idea to their knowledge of the context?
4) How can I draw attention to the context throughout the lesson (for example, invite personal anecdotes or share my own, clarify confusing language, or use a picture or video as a visual aid)?	

6 Conclusion

The future of contextual tasks likely includes more meaningful modeling and fewer traditional story problems. With some thoughtful planning and implementation, we can maximize the potential of contextual tasks to engage our students' minds and hearts for mathematics!

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